Woods Hole Oceanographic Institution
Woods Hole, MA 02543
Phone: (508) 548-1400
Telex: 951679

June 3, 1994

(3)

Dr. Robert Abbey
Office of Naval Research
Marine Meteorology (Code 322 MM)
Ballston Tower 1
800 N. Quincy
Arlington, Virginia 22217-5000

Dear Bob:

This is a Final Report on Contract N00014-90-J-1423, which was our participation in ERICA (the Experiment on Rapidly Intensifying Cyclones over the Atlantic).

The goal of the Experiment on Rapidly Intensifying Cyclones over the Atlantic (ERICA) field study was to obtain a new understanding of the physical mechanisms and processes that account for the wintertime phenomenon of explosively developing extratropical cyclones over the North Atlantic Ocean (Hadlock and Kreitzberg, 1988). The intensive field program ran from 1 December 1988 to 28 February 1989, focusing on a region north of Cape Hatteras to beyond New Foundland, east of Cape Cod, and south of Nova Scotia. The focus of our participation in the field program of ERICA was a mooring deployed at 42° 33'N, 61° 14'W for the duration of the experiment. This mooring was equipped with two meteorological packages and two Vector Measuring Current Meters (VMCMs). The meteorological packages measured wind speed and direction, barometric pressure, sea surface and air temperatures, relative humidity, incoming shortwave radiation, and incoming longwave radiation. The VMCMs measured currents and temperature at 20 and 50 meter depths. During the experiment one 15-minute average of the meteorological data was transmitted each hour from each package via ARGOS and made available to other ERICA investigators on a dial-up data base maintained at WHOI. We were also supported to provide a scientist (G. Crescenti) to participate in ERICA aircraft flights.

The objectives of our later analysis effort were to: 1) document the variability observed at the mooring in the surface meteorological fields and in the upper ocean; 2) compute time series of the air-sea fluxes of momentum, of sensible and latent heat, and of shortwave and longwave radiation; and 3) investigate the response of the upper ocean to wintertime atmospheric forcing including the storms that were the focus of the ERICA Intensive Observation Periods (IOPs). In cooperation with other ERICA investigators we sought to determine the extent to which air-sea interaction, especially in the form of sensible and latent heat flux, played a role in the rapid intensification of the storms observed during the IOPs.

The Woods Hole Oceanographic Institution (WHOI) surface mooring (Figure 1) was placed close to the approximate latitude of maximum "bomb" occurrence (Roebber, 1984). The buoy was deployed on 17 October 1988 and recovered on 7 March 1989. Buoy Group. Figure 2 shows the tracks of three storms relative to the position of the buoy. Figure 3 provides an example of the data and shows the basic meteorological data from IOP (Intensive Operating Period) 2. Note that the winds peaked at nearly 25 m s^{-1} and that air temperatures went below -4°C. Pre- and post-calibration results were used to produce final versions of the basic time series used in our analyses and supplied to the other ERICA investigators (Berger and Friehe, 1994, for example). To gain permission to moor the buoy at the location chosen, we signed an agreement to provide the Canadian government with the copies of the data; that obligation was fulfilled. A technical report (Crescenti et al., 1991) was written describing the methods used to obtain the data and containing time series plots. Copies of this report and the of the data were sent to the Canadian government and to the ERICA data archive.

We published the results of the science analyses in Crescenti and Weller (1992). The variability in the atmosphere and ocean associated with the several storms that passed close to the buoy are described. In addition, we examined a simple heat budget of the upper ocean and contrasted the heat lost or gained by the upper ocean with the local air-sea exchanges. The total surface heat flux at times exceed 1,000 W m^{-2} (into the air). However, in this coastal location the heat budget of the ocean was dominated by advection rather than by local air-sea exchange. If the coastal currents came from the south and that ocean temperatures to the south were warmer, bringing warm water into the region, it could be hypothesized that the role of the oceanic advection was to maintain a source of heat for the atmosphere. In this case, however, the current meter data showed a strong locally forced velocity response in the upper ocean;

and this response was dominated by the transport of surface water to the south by persistent westerly winds coming off the North American continent. In this case, then, it was found that the source of heat for the upper ocean north of the region of the bombs needs to be considered. It was clear though that local vertical mixing in the ocean does not lead to a persistent local cooling of the sea surface and related modification of the air-sea flux of heat; horizontal advection replenishes the surface layer of the ocean with water from outside the region of the storm track.

In addition to the science results summarized above it is important to note that the work produced new technical innovations. Special efforts focused on the design of the mooring line and on the buoy hull. The mooring design worked identified the effort as an attempt to design a Severe Environment Surface Mooring (SESMOOR; Kery, 1989). The work on the hull focused on developed a buoy that would not suffer from ice buildup during the high wind, freezing spray conditions typical of the area.

The design of the buoy that resulted, with a single central mast, was extremely successful. It formed the starting point for a buoy hull configuration for the TOGA COARE (Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Experiment) and for flux buoys now under design that will carry sonic anemometers. The successful deployment of the meteorological sensors in such conditions has been followed by further research on ice-resistant coatings. This work can form the basis for development of meteorological buoys for work at high latitudes and winter conditions similar to those seen in ERICA.

We feel that we both contributed to and learned from ERICA and look forward to future work with the ONR Marine Meteorology Program.

Sincerely yours,

Robert A. Weller

Robert A. Weller

cc: Dr. Robert Abbey, Code 322MM (3)
Administrative Grants Officer (Mr. Robert Tanner) (1)
Director, Naval Research Laboratory (1)
Defense Technical Information Center (4)

References:

Berger, B. W. and C. Friehe, 1994: Boundary-layer structure near the cold front of a marine cyclone during ERICA. Boundary Layer Meteorology, submitted.

Crescenti, G. H., S. A. Tarbell, and R. A. Weller, 1991. A compilation of moored current meter data and wind recorder data from the Sever Environment Surface Mooring (SESMOOR). W. H. O. I. Tech. Rep. WHOI-91-18, 59 pages.

Crescenti, G. H. and R. A. Weller, 1992: Analysis of surface fluxes in the marine atmospheric boundary layer in the vicinity of rapidly intensifying cyclones. Journal of Applied Meteorology, 31(8), 831-848.

Hadlock, R. and C. W. Kreitzberg, 1988: The Experiment on Rapidly Intensifying Cyclones of the Atlantic (ERICA) field study: Objectives and plans. Bulletin of the American Meteorological Society, 69: 1309-1320.

Kery, S. M., 1989: *Severe Environment Surface Mooring* (SESMOOR). Oceans '89, IEEE, Seattle, Washington, pp. 1398-1405.

Roebber, P. J., 1984: Statistical analysis and updated climatology of explosive cyclones. Monthly Weather Review, 112: 1577-1589.

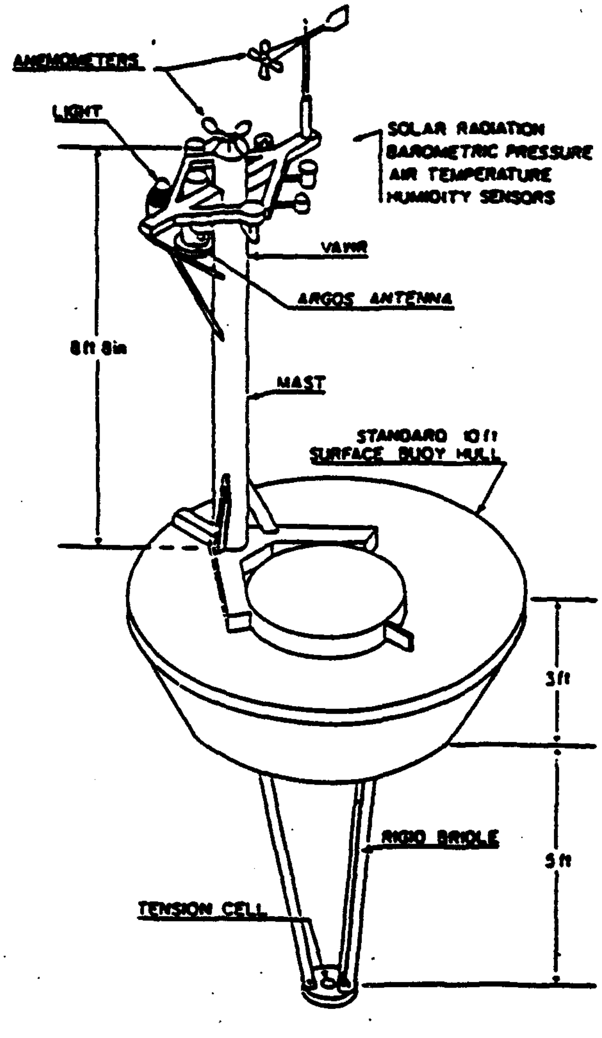

Figure 1. Line drawing of the buoy designed specifically for ERICA.

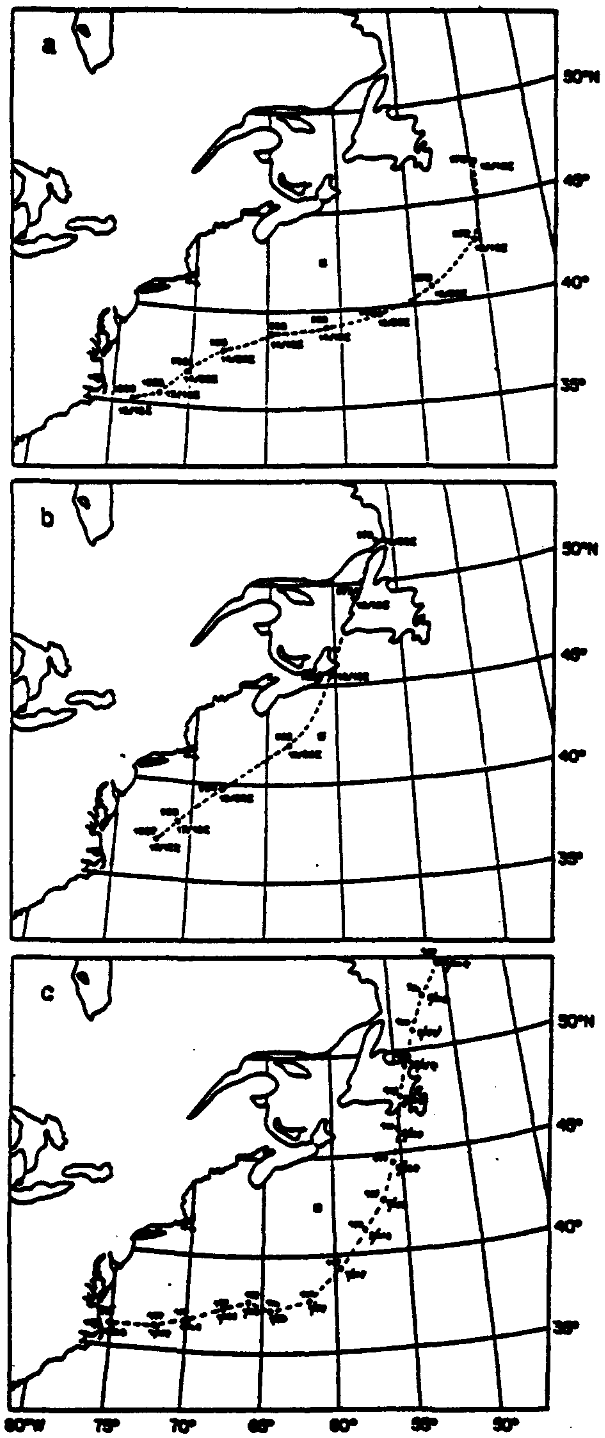

Figure 2. Storm tracks relative to the WHOI ERICA mooring (black square) for IOP 2 (a), IOP 3 (b), and IOP 4 (c). Cyclone center barometric pressure is given in mb along with date and time (UTC).

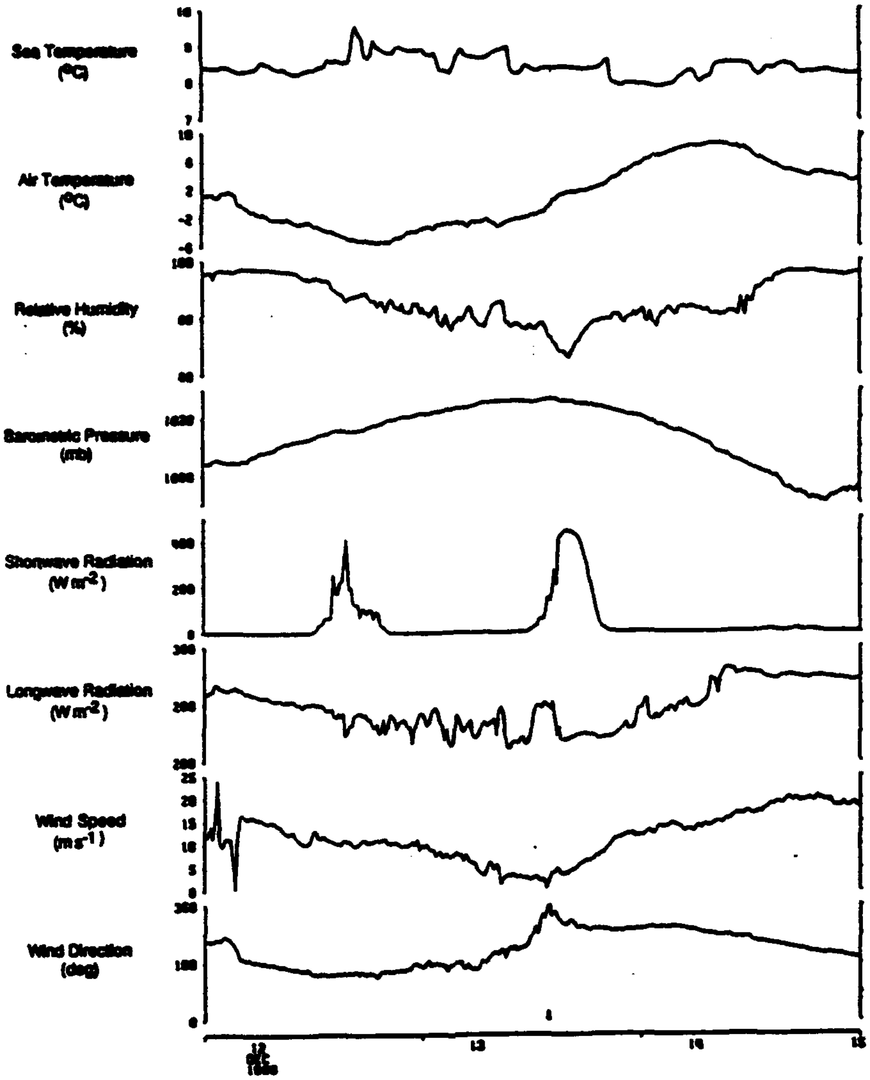

Figure 3. Surface meteorology measured by the ERICA WHOI buoy for IOP 2. Note that wind peaked near 25 m s^{-1} and that air temperatures went lower than 4 °C.